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Chapter 10. Desalination (Brackish and Sea Water)

Desalination, the removal of salts from saline waters, is one of the few options to augment California's water supply without competing with other inland freshwater uses, both human and environmental. The vast Pacific Ocean would even appear to be an endless supply, yet desalination faces cost and environmental challenges. The challenges are less with desalinating brackish groundwater — there are approximately 20 such sites around the state providing high-quality water to their customers. Even desalinating ocean water is already in the realm of feasibility, with eight operating seawater desalination facilities, including those taking ocean water from the sands under the ocean floor.

This situation highlights the diversity of California's water supply contexts and reinforces the fact that there are no absolutes in California water. Desalination is not a viable water supply for many water suppliers in the state, but for some it could make a significant contribution. How those California water suppliers move forward with implementing environmentally protective projects is a key issue facing multiple California communities.

Introduction

This Desalination Resource Management Strategy (Desal RMS) addresses key sea water and groundwater desalination issues and challenges. It also provides a framework for how California communities and water users may move forward with ocean and brackish water desalination. It

- Presents water desalination concepts and issues.
- Identifies where desalination is currently occurring and is being considered in California.
- Addresses issues related to a balanced approach to how desalination could support water sustainability in the state.
- Identifies recommendations for water suppliers and agencies to consider when evaluating desalination opportunities.

This Desal RMS focuses on presenting a strategy for sustainable desalting of surface and subsurface waters of the state for the principal purpose of meeting municipal drinking water demands. It discusses desalination technology, as well as the legal and institutional framework to consider when planning and implementing projects. The Desal RMS also addresses costs and environmental impact issues. Desalinating water for uses other than community water supply, such as large-scale agricultural, industrial, and mining activities, is not addressed in detail in this chapter but may be discussed briefly within the overall context of desalination technology or implementation of the practice.

Because of the complexity of desalination and the various ways desalination technologies are implemented in California, the Desal RMS presents brief summaries of key issues here. Additional detail about desalination technologies and issues are presented in Volume 4, *Reference Guide*.

Definition of Desalination

Desalination is the removal of salts from water to produce a water of lesser salinity than the source water. Other terms that are interchangeable with desalination include seawater or saline water conversion, desalting, demineralization, and desalinization. For consistency, "desalination" will be used in this chapter. Regardless of the terms chosen, the fundamental meaning is the removal of salt from a fluid.

Desalination can be used to reduce salinity in many types of water. The term ‘source water’ is used to identify the body of water from which water is taken for beneficial purposes. Source water for desalination can include ocean water, groundwater, and municipal wastewater. Desalination can be used to reduce salts in water or can produce water to drinking water standards. Desalinated water can be used for potable uses, such as municipal drinking water, or non-potable applications like agricultural irrigation or industrial processes.

Sustainability is a common theme of the California Water Plan (CWP) and an objective in the planning and management of water desalination. As used in this plan water sustainability is the dynamic state of water use and supply that meets today’s needs without compromising the long-term capacity of the natural and human aspects of the water to meet the needs of future generations.

Salt and Salinity

Many details about water chemistry, drinking water regulations, and the interactions between water bodies are beyond the scope of this chapter but play a significant role in setting State, regional and water quality and supply objectives and implementing a desalination strategy. Basic concepts and terms regarding salts and salinity of water are discussed below.

Salts occur naturally in the environment, but human activity often increases salinity in water and soil. Because of the negative impacts of salinity on human use or the water environment, salinity management is a critical resource management strategy. See Chapter 19, “Salt and Salinity Management” for additional information on this issue.

Description of Salts and Their Origin

The presence of certain impurities (e.g., minerals, elements, and chemical compounds) in water, especially at higher concentrations, affects the aesthetics or use of water. For example:

- Halite, the mineral commonly known as table salt or sodium chloride (NaCl), readily dissolves in water into ionic forms and is found objectionable to human taste even at low levels.
- Sodium, the element (Na), can affect soil properties damaging crops.
- Calcium carbonate (chemical compound, $CaCO_3$) deposits on household fixtures and industrial equipment causing damage or increasing maintenance.

When solid substances mix with water or other liquids, they may separate (dissolve) into two parts, one with a positive charge (such as sodium or calcium) and one with a negative charge (such as chloride or bicarbonate). This form of a dissolved solid is termed an ionic substance. The majority of dissolved solids in raw and finished municipal water supply sources, fresh or saline, are ionic inorganic substances such as calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, bromide, and nitrate. These dissolved ionic elements or compounds are known collectively as “salt”.

The principal source of salt in the oceans and brackish waters is from the land. The salts are leached out a bit at a time as water flows over and through the land during each hydrological cycle. Over the millenniums, the oceans, seas, and other saline bodies of water have become salty through the action of fresh water interacting with rocks containing minerals, like the sodium chloride compound, to make them salty. After water evaporates from the surface of a saline water body, the salt is left behind further increasing the salinity. The oceans have developed a noticeably salty taste. The ocean and some inland low-lying bodies of water without drainage accumulate salts, and thus are called “salt sinks.” Salt sinks have traditionally not been used for municipal water supplies in California.

Salinity Measurements

The saltiness of water is referred to as its salinity. "Salinity" is generally defined as the amount of salt dissolved in a given unit volume of water. It is variously measured in units of electrical conductivity (EC), total dissolved solids (TDS), practical salinity units (PSU), or other units depending on the scientific discipline of the person doing the measuring and the purpose of the study or monitoring program.

The unit of measure most often used for TDS is milligrams per liter, mg/l. Since one liter of pure water weighs one million milligrams at a referenced temperature, TDS is expressed as parts per million, ppm, parts per thousand, ppt, as well as percent salinity. The generally accepted value for salinity of open sea water is a TDS of 35,000 mg/l or ppm, also expressed as 35 parts per thousand (ppt) TDS or 3.5 percent salinity (3.5 percent salt). TDS is one of the bases for federal and State standards for how much dissolved material is in a water supply.

While TDS is often the measurement of salinity, it should be understood that the TDS measurement includes other dissolved chemicals besides salts, including metals such as copper and iron and elements like boron. Also, sodium chloride is often the most common and highest salt ion concentration in water and is the salt most frequently equated to salinity. While sodium chloride may be the most common salt, many other dissolved salts in ionic form are found in natural waters.

There are a number of ways to measure saltiness in water or soil with each having its role in various sciences (e.g., oceanography, hydrology, and geology). The most used metrics are shown in Table 10-1.

PLACEHOLDER Table10-1 Measurements of Salinity

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Degrees of Salinity

There is no fixed delineation between "fresh" and "brackish" water; as such and for this chapter, a TDS concentration value of 1000 mg/l or 0.1 percent salinity is used for the dividing line, which is consistent with many references.

The term "brackish", in general, refers to water that has more salinity than fresh water but less than sea water. There also is no rigid delineation between brackish water and seawater; however, 30,000 mg/l or 3 percent salinity will be used for the purposes of this chapter to make a general delineation between brackish and sea water.

The average salinity of seawater is generally taken to be 35,000 ppm TDS or 3.5 percent. The range of salinity in ocean water varies and for the purposes of this chapter the range is established from 30,000 mg/l to 50,000 mg/l, which can include inland seas, such as the Salton Sea with a rising salinity currently near 44,000 mg/l TDS.

The term "brine" is a general term having different meanings in industry, water management, and even household cooking. Brine may refer to any naturally occurring water with a salinity higher than seawater or to reject water from a desalination facility. In many food preserving processes, brines are used of varying salinity to achieve a specific purpose. For the Desal-RMS, the term "brine" refers to the high salinity reject water normally associated with the treatment processes used to remove salts. While the reject water from a desalination facility using reverse osmosis technology may be referred to as "brine", it may have concentrations as low as 4,000 mg/l TDS, such as in the case of desalting brackish groundwater. Thus, the term brine remains relative to the context used. Natural brines, like those found under the Salton Sea and other geothermally active locations in the state, are usually hot with salinities much higher than seawater. The Salton Sea natural brines are approximately 280,000 mg/l TDS or 8 times that of average surface seawater.

Table10-2 below provides a few general salinity ranges in TDS for water quality classification purposes.

PLACEHOLDER Table10-2 General Water Salinity Levels Based on Total Dissolved Solids (TDS)

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Fresh, brackish, and sea are qualitative terms that do not necessarily specify an origin or the exact environment from which a water withdrawal is made. There is often a common inference that the term “brackish” refers to groundwater and that “seawater” refers to surface water from the sea. Water characterized by the terms fresh, brackish, or sea may be withdrawn from surface and subsurface locations. Because “brackish” and “seawater” are not locations but are better descriptors or degrees of salinity, there should be no inferences made associating “brackish” water to subsurface (groundwater) and “seawater” with open or surface water in discussions concerning desalination or saline waters. The subtitle of this chapter denotes “Brackish and Sea Water” as the two main types of saline water available in the state requiring desalination regardless of whether they are surface or groundwater in origin.

Sources of Water for Desalination in California

General

This section considers water sources suitable for municipal drinking water supply using desalination technologies. While desalination technologies also have the potential to treat municipal wastewater suitably for direct potable reuse, that topic is not covered in this chapter but in Chapter 12, “Recycled Municipal Water.”

Typically, raw water sources must meet basic municipal water supply development criteria for quality and quantity. Municipal source waters should be capable of providing an adequate and sustainable amount of water for an intended beneficial use. Potential sources include oceans, bays, rivers, lakes, and groundwater aquifers. The determination of the safe yield from a water body is necessary for desalination as well as many other types of water supply projects. The ocean and other saline open water environments afford the greatest safe yield potential for desalination water supply projects in California.

Typical water source types used for municipal water supplies throughout California, including those requiring desalting to provide a fresh drinking water, together with a typical treatment facility are shown in Figure 10-1.

Figure 10-1 Basic Municipal Drinking Water Facility and Source Waters in California

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

As a general rule most water sources with a TDS concentration higher than 1,000 mg/l are termed brackish and will need desalination treatment or blending with fresher water to meet municipal drinking water quality criteria.

Source Water Classifications

Differences between sources of water suitable for desalination relatively affect cost, environmental impacts, greenhouse gas emissions, and other feasibility factors. For this and other reasons, it is important to classify water by source and quality for further discussion.

Water bodies are generally classified as either surface or subsurface (groundwater). Although, the term "surface water" is often used to denote only fresh surface water. In this chapter, the term "surface water" does not denote water quality such as the salt content and includes saline waters such as the ocean, marine bays, or other saline water bodies in addition to the traditional fresh water lakes, rivers, wetlands, and other surface water bodies. Water bodies are generally classified as either surface or subsurface (groundwater). Some water sources are further typed with distinctions to improve delineation.

For purposes this chapter, the following classifications of source waters are made:

- Open sea water (surface).
- Open fresh water (surface).
- Groundwater (subsurface).
- Groundwater (subsurface) under the direct and natural influence of a surface water such as the sea
- Confined groundwater with limited natural reoccurring recharge from annual precipitation.
- Brackish surface water such as an enclosed bay or estuary, which may be fresh or saline dominant depending on a mixing zone or seasonal variations.

In addition to surface and subsurface or ground water classification, there are qualitative salinity descriptions such as fresh, semi-fresh, brackish and sea. Because the term "sea" can refer to both location and water quality; we are compelled to add more adjectives providing a more precise description of a water body such as open and inland as in the "open sea" or the "inland sea". (California's Salton Sea, an inland sea, is an example of a surface water body with a higher salt content than found in the open ocean.

PLACEHOLDER Figure 10-2 General Distinctions for Location

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

The general distinctions for location and relative quality given in Fig. 10-2 above and additional terms added as necessary will help describe the general distribution of water relative to depth and source in the state.

Describing a water body using the terms "fresh", "brackish", "sea", or other characterizes the degree of salinity or freshness of source water and it depends the context. Table 10-2 provides a convenient gradation using these common terms as they are used in this chapter.

Table 10-2 Gradation Common Terms

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

It is convenient to type brackish groundwater into main categories related to the natural hydrological cycle, replenishment, and hydrogeological interconnectedness with fresh and saline waters:

- Type I – Groundwater is replenished by freshwater sources or other brackish groundwater. There is little to no interconnectedness to a seawater source of replenishment. Brackish groundwater extractions may adversely impact fresh groundwater supplies.

- Type II-- Groundwater is replenished by both seawater and freshwater sources. There is a connection between fresh water and seawater sources. The interface between these sources is subject to change based on the hydrologic cycle, groundwater extractions, and seawater elevation. Brackish groundwater extractions may adversely impact fresh groundwater supplies.
- Type III-- Groundwater is replenished by a seawater source with no connection to freshwater sources. Brackish groundwater extractions in this environment are not likely to adversely impact natural freshwater supplies, surface or groundwater. Further distinctions may be made as to the degree of the open seawater direct-influence.

Subsurface Water

This section of the chapter provides information about issues that can occur from extraction of water that is present below the land surface, groundwater, for municipal drinking water purposes.

When considering a water source for water supply it is imperative to determine the safe yield of the water body. Safe yield of a groundwater basin or aquifer system is defined as the amount of water that can be withdrawn from it without producing an undesirable effect (Todd, 1959). The safe yield should not deplete or overdraft the water reserves. The yield should not cause intrusion of lower quality water into the aquifer. This lower quality water includes seawater, polluted, as well as waters of a lesser quality. Additionally, the safe yield should not cause land subsidence. Surface water bodies such as streams or lakes connected to aquifers might become depleted through the extraction of groundwater and infringe on water rights. Note that anything in excess of the safe yield is an overdraft.

When the safe yield of a subsurface water source is limited, it may be best to reserve the water for emergencies such as droughts.

Seawater intrusion is the subsurface flow of seawater into a subsurface water body. The higher density of seawater allows it to flow beneath the fresher water and move inland. Extraction exacerbates the inland flow by lowering the water level and reducing the overlaying pressure, allowing seawater to flow further inland. Because seawater has very high salt content, the influx causes a degradation of water quality. This results in higher water treatment costs. Brackish groundwater extraction near the coast could exacerbate seawater intrusion.

Because aquifers are often interconnected to surface water bodies such as streams or lakes, groundwater extraction affects these surface water sources. Some of these ecological impacts include surface water depletion, loss of the surface water habitat, which affect fisheries, wildlife, and plants, and land subsidence, among others. The known ecological impacts of groundwater overdraft in California include diminished stream flow and lake levels, damaged vegetation, and corresponding effects on fish and migratory birds.

A notable distinction between groundwater and surface water is that unlike seawater and its corresponding marine environment, the public does not directly associate groundwater with an important ecological habitat; there are no groundwater species included on the federal endangered species list to date. This belief engenders the claim that desalination of brackish groundwater occurs with brine disposal as the only major ecological or environmental impediment other than GHG emissions associated with energy consumption. The interaction of groundwater with surface water needs to be considered.

Surface Water

Since seawater is the major source of surface waters for purposes of desalination this section will focus on this water source. This supply alternative is unique in that seawater is not dependant on the hydrologic cycle and can produce fresh water reliably even with the climate change projected droughts (NAP, 2008). At the same time, the sea provides vast resources beyond just a possible raw water source for meeting our freshwater demands. This section will focus on presenting the factors, which set the seawater environment apart from the brackish groundwater.

Seawater contains an array of nutrients supporting plankton blooms and is the broth for much of the marine environment's food web. The marine waterscape includes forests of kelps where young and mature fish and seals dwell along with crabs, snails, and other species of mammals, fish, and invertebrates.

While 35,000 ppm TDS is the average salinity of open sea water, scientists know that salinity naturally varies throughout the open oceans and seas and plays a role in global climate. Some marine life depends on a narrow range of salinity fluctuations. Marine biologists are trying to understand just how sensitive certain marine environments, such as the benthic regions on the ocean floor, are to changes in salinity levels. Since the discharge of brine could affect salinity levels, this could increase the mortality of the marine life, an undesirable effect.

Note that the safe yield of a surface water body is the annual amount of water that can be removed sustainably without interfering with water rights. Because of the great volume of water in the oceans, ocean and other saline open water environments afford the greatest safe yield potential for desalination water supply projects in California. However, local physical constraints and environmental concerns limit the potential safe yield.

Although the oceans may be said to be inexhaustible, the term should be used with caution. The sustainable extraction of seawater for desalination to meet municipal freshwater demand is dependent upon safeguarding the seawater environment; the seawater environment and the marine life that lives in it is not "inexhaustible".

Desalination as a Water Treatment Technology

Introduction

Desalination as already defined is the removal of salts from water to provide a water of lesser salinity than the source water. Salt is but one of many contaminants found in source water used for municipal drinking water. There are many types of processes using various water treatment technologies to remove these contaminants. More information may be found on drinking water treatment in California in Chapter 15 of CWP.

Aside from the treatment technology to remove the salts, a desalination project must include other elements to convey and additionally treat the source water and to deliver the finished water to customers. Figure 10-3 depicts key elements of a desalination system as will be discussed later in this section.

PLACEHOLDER Figure 10-3 General Desalination System Schematic

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Not all elements, as shown in Fig. 10-3, are necessary for all desalination systems. The "Pretreatment", "Post Treatment", "Blending", "Solids Disposal", and "Concentrate" elements do not occur in all desalination systems while the "Raw Water", "Intakes", "Desalination", "Finished Water", and "Distribution" elements are always part of full-scale desalination systems. The elements of "Raw Water" and "Distribution" in this schematic are included to emphasize that where the water comes from and where it ends up are part of a desalination system as they affect feasibility, design, and environmental impacts.

Other common terms may be used when discussing treatment processes. Here are a few: “component” is widely used instead of “element” in many textbooks, “product water” and “permeate” may be used instead of “finished water”, “feedwater” and “influent” are often used instead of “raw water”.

This section will (1) provide an overview of the types of desalination technologies available and under research, (2) give some detail on the desalination technology known as reverse osmosis (RO), and (3) present the various elements of a municipal drinking water system using the RO technology for desalination.

Overview of Types of Desalination Technologies

The processes, technologies, and methods used to achieve a desired level of salt removal in water include a wide range of products and systems. This overview provides general information on both established and new or emerging desalination technologies.

Table 10-3 provides a list of desalination technologies and their general application. It is convenient to place desalination technologies or processes into three main categories: (1) thermal (2) membrane separation, and (3) all others.

Table 10-3 General Desalination Technology List

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Thermal Distillation Processes

The oldest desalination process is distillation, which has been used for over 2000 years. Thermal desalination processes render safe and reliable water from almost any raw water source including fresh, brackish, and sea water sources. The basic concept behind distillation is that by heating an aqueous solution one can generate water vapor. The water vapor contains almost none of the contaminants, like the salt or other materials originally found in the source water. If the water vapor is directed toward a cool surface, it can be condensed to liquid water containing very little of the original source water contaminants. This condensed water vapor is the product water of the desalination processes using the thermal distillation principles. The salts and other contaminants accumulated in this process are managed as solid waste. These solid wastes may have value in the commercial and industrial marketplace.

Most large scale thermal distillation facilities are coupled with power plants that use steam turbines to generate electricity. Waste heat (i.e., energy) from the cooling of the power generation system can be used in the distillation process to reap benefits of a “cogeneration” approach to produce drinking water and electric power in the same complex. No municipal drinking water in California is produced with a thermal distillation process. Many of the large scale facilities using thermal processes at the municipal or industrial level are in Middle Eastern countries.

Two of the most widely used thermal processes for seawater desalination are Multi-Stage Flash evaporation (MSF) and Multi Effect Distillation (MED). The most widely used distillation process is Multi-Stage Flash evaporation (MSF). Among the advantages of MSF and other distillation processes is that the composition of feedwater has an almost negligible affect on the energy required to produce a volume of product water. The processes deliver exceptionally high purity water (less than 25 mg/l TDS) and have been successfully operated in very large sizes. Among the disadvantages are the high capital cost and the requirement for a large input of heat. Thermal desalination processes work well at the scale related to the energy readily available through cogeneration or other natural heat sources (e.g., geothermal heat source).

At least one new thermal process concept has been proposed for possible use in California that claims to eliminate brine wastewater discharge back into the environment, operates with higher efficiencies than other distillation processes, and management of solid waste includes recycling mineral recovery products into the industrial complex (United States Patent 8,946,787).

Membrane Separation and Reverse Osmosis Technologies

Many ways have been developed to separate salt from water. Membrane separation technologies are most commonly used for desalination. A membrane for this purpose is a thin, film-like material that separates two fluids. It is semi-permeable, allowing some particles or chemicals to pass through, but not others. The objective is to allow water to pass through the pores in the membrane and prevent the passage of other substances. In reality, what is filtered out depends on the size of the pores and the type of material used for a membrane. Reverse osmosis (RO) membranes are most effective for salt removal, but no membranes result in pure water. Categories of membranes with increasingly smaller pores are microfiltration, ultrafiltration, nanofiltration and RO. Examples of the substances removed by membranes are illustrated in Figure 10-4. A brief description of membranes is also given in Table 10-4.

PLACEHOLDER Figure 10-4 The Filtration Spectrum

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

[PLACEHOLDER graphic Taken from Advanced Membrane Technologies, Stanford University, May 07, 2008, Mark Wilf, Ph.D. Tetra Tech, need permission or need to develop our own. Many of these types of charts exist. Filename Membrane_types.pdf]

Table 10-4 Brief Description of Membranes

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

A schematic representation of the membrane process is shown in Figure 10-3. The product water is the permeate, which is desalinated water in the case of RO. The reject water is brine in the case of RO. Brine management is a key issue that is discussed later in this chapter. RO membranes typically come in the form of rolls called cartridges. The membrane sheets are sandwiched between spacers to allow feedwater to enter one side of the membrane and permeate water to pass through and leave the other side. The salts are left behind on the feedwater side of the membrane and build up in concentration, becoming brine. All assembly of RO cartridges look like the view in Figure 10-5.

In general, an energy input is required to use membrane separation. High pressures are needed to get water molecules to pass through the membrane at fast enough rates for functional municipal scale applications and to overcome the inherent properties of the membrane. The amount of energy required, generally, increases as the particle size decreases and salt concentrations increase. Energy is a major factor in desalination, especially seawater desalination, and is discussed further in the issues section of this chapter.

Among the various membrane separation technologies listed in Table 10-3, reverse osmosis (RO) has matured rapidly over the last few decades and has become the process of choice for many desalination projects. In the USA, it has become the most economic process and is now widely utilized in the Southeast, Southwest, and West to provide an alternate source of supply derived from saline surface and groundwater. Because of its current prevalent position in the desalination arena in California, RO will be the focus of further discussion of desalination in this chapter.

Basic Elements of a Desalination System

Each of the elements of a desalination system, as shown in Figure 10-3, is discussed in this section. There are distinctions between systems using surface sources (mainly seawater) and subsurface sources (brackish groundwater or groundwater under the direct influence of surface seawater). The differences will be described. Figure 10-3 is a simplification of a desalination system. There are systems that omit one or more of these elements, arrange the elements in a different order, or combine elements into various combinations representing one component of a single facility.

Raw Water

The raw water element as the source water for desalination, also referred to as feedwater. Encompassed in this element is not only the water itself but also the geophysical characteristics of the environment containing the water. The raw water characteristics affect the capability of a particular location to serve as a water source, the design of facilities to accomplish water extraction, and the protection needed for the environment and the raw water for long term sustainability.

The typical raw water factors for surface water intakes that must be considered include oceanographic conditions, limnology of fresh water bodies, hydrogeology, episodic water quality changes, benthic topography, pollution, and adverse impacts to aquatic species. A surface water source supports an aquatic ecology that is especially susceptible to damage caused by water intakes. Design features can minimize those effects, as described in the next section, but mitigation measures may be needed to compensate for unavoidable impacts.

Typical raw water factors to consider for subsurface water intakes include water quality, long term safe aquifer yield, interaction with surface water, and seawater intrusion impacts. Subsurface intakes, under the ocean floor or at inland near shore locations, can be a means of using seawater while avoiding surface water intake effects on aquatic organisms. However, they can also cause seawater intrusion into or depletion of inland freshwater aquifers.

Intake

The intake element consists of the entrance structure where raw water is withdrawn, a pipeline to convey the water to the desalination and other water treatment facilities, and pumps to lift and move the water. It is common to include a pretreatment element, a screen, at the water intake to avoid sucking in aquatic organisms and undesirable suspended debris or, in the case of groundwater wells, sand or other particles. Discussion of intakes will include these associated screens.

For surface water intakes, particularly for ocean water, impingement and entrainment of organisms are key concerns. Impingement occurs when organisms sufficiently large to avoid going through the intake screens are trapped against the screens by the force of the flowing source water. Entrainment occurs when aquatic organisms enter the desalination plant intake, are drawn into the intake system, and pass through to the treatment facilities. Impingement typically involves adult organisms (fish, crabs, etc.) that are large enough to actually be retained by the intake screens, while entrainment mainly affects aquatic species small enough to pass through the particular size and shape of intake screen.

Intake systems may require under-water activities including excavation, dredging, embedment, pipe laying and anchoring. The construction impacts might be minimized by sharing intakes with other facilities, such as power plants, or using existing infrastructure no longer needed for its original use.

Figure 10 –X illustrate examples of screened intake structures currently used in seawater desalination systems. **[One or more of these figures will be used.]**

Pretreatment

Desalination treatment technologies, especially RO, require a feed water minimum quality to avoid facility damage, corrosion, membrane fouling (clogging), impaired performance, or excessive maintenance. Raw water often needs to be conditioned through pretreatment to provide a water suitable for the desalination element. Intake screens are often the first pretreatment component to remove weeds, algae, fish, shells, and other larger particles. Certain source waters are subject to contamination by natural toxins generated by algal blooms (red tides), wastewater discharges (point and non-point), oil and hydrocarbon residues or spills, urban runoff, and agricultural pollution such as animal wastes, fertilizers and pesticides. Pretreatment ahead of RO membranes often includes disinfection, biocide, and other chemical additives to control biological growth, scaling, and corrosion effects. Pretreatment may also include other membranes, such as microfiltration, to improve the efficiency of RO.

Subsurface intakes have another form of pretreatment — the filtering effect on water flowing through sediments in the ground. To avoid impingement and entrainment effects on aquatic life, subsurface intakes from wells under the ocean floor can be used if the right geologic conditions exist. Figure 10-6 Intake 2 & 4 provides a cross-section view of a typical engineered gravel-packed well.

Figure 10-6 Cross-section View of a Typical Engineered Gravel-packed Well

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Blending

Blending may occur before or after the desalination treatment element. The water used for blending may be another raw water source or potable fresh water. The purposes for blending include improving either the desalination operation or the aesthetics of the finished water for customer acceptance.

Desalination

The function of the desalination treatment element is the removal of salts and other contaminants. It is the core of a desalination system. RO is the most common desalination technology for producing potable water. This element also includes pumps to force water through the RO membrane and energy recovery devices. Because of the high pressure needed for RO, desalination treatment is the most energy intensive element of a desalination system, even with energy recovery devices. While RO is used to treat both brackish water and seawater, because of the lower salt content of brackish water, the energy needed for brackish water is much less than for seawater treatment. Energy needs are discussed later in this chapter.

There are two products from RO treatment, the permeate (desalted water) and reject brine (ultra salty wastewater).

Post Treatment

Permeate water leaving the RO process can be acidic and has little hardness. It can be corrosive to pipes and have an unnatural taste and feel. Post treatment may include addition of chemicals to produce an acceptable water from the consumer perspective. Blending with another source of water is another way of adjusting the quality of water. Post Treatment includes providing the necessary disinfection treatments to produce a finished water.

Finished Water

The finished water element has been included in the discussion to show the end product of the treatment elements involved in an RO facility. At this stage, the water may be served to customers through the distribution system.

Distribution

The distribution element consists of the facilities needed to convey the finished water to the consumer. The facilities are pipelines, pumps, and storage tanks. Most communities considering desalination already have a water distribution to deliver their existing sources of water. When a new desalination treatment plant is constructed, a pipeline is needed to connect the desalination treatment facility to the existing distribution system. If the source of brackish or seawater is far from the existing distribution system, the connecting pipeline and associated pumps or tanks could be expensive. If the existing distribution system is not designed to receive a large new flow of water, modifications to the existing system may be necessary.

Solids Disposal

[Under development, not available at this time]

Concentrate Management (reject, brine, waste)

[Under development, not available at this time]

Desalination in California

Desalinated water currently is one of California’s lowest volume potable water supplies. However, desalination of groundwater and ocean water is being considered more frequently as water supplies become constrained, more local supplies are sought, and technologies improve and become more cost-effective. Additionally, with submittal of their 2010 urban water management plans and the IRWM State funding program, California water suppliers are now required to evaluate desalination of brackish groundwater and seawater as a method to meet their water resource management goals and objectives.

For most California water suppliers, desalination is neither practical because a brackish or saline water source is not nearby nor is it economically feasible because more cost-effective water supplies are available. However, desalination is increasingly being considered a supply worth evaluating, particularly where current water supplies are strained. Some of these evaluations have become high-profile and vociferous, but they have resulted in very important water supply reliability and sustainability discussions.

There are approximately 840 miles of general coastline and about 3,427 miles of tidal shoreline in California.

History of Desalination in California

The first major facilities involving desalination came online in the 1960s, primarily to support cooling processes at power plants such as PG&E’s Morro Bay and Moss Landing facilities. Since then, desalinated sea water has been successfully integrated into industrial and non-potable uses at multiple coastal sites.

In the 1960s, it was envisioned that desalination could play an increasing role in California's water supply and power generation needs. In the 1960 transmittal letter for DWR Bulletin 93 entitled "Saline Water Demineralization and Nuclear Energy in The California Water Plan", DWR Director Harvey O. Banks wrote to Governor Edmund G. Brown and members of the Legislature of the State of California:

> "Although no saline water demineralization technique yet developed can compete with the costs of large scale development of natural sources of water in California, it is probable that saline water conversion plants will have a definite place in the water program. The Department of Water Resources will continue to take a definite and continuing interest in those areas of research and development that may have promise of eventually producing low cost converted water."

Desalination technologies were extensively tested in California in the late 1950s and early 1960s to address water supply issues. Experiments and pilots testing of different technologies and projects were conducted using both ocean and groundwater source water (DWR 1960 and 1962). Desalination was also considered as part of the San Joaquin Valley Drainage investigation.

Coalinga was the site of the first operational brackish groundwater desalination facility. It operated from 1959 to the early 1960s, reducing groundwater salinity from 2,100-2,400 to under 500 mg/L (DWR 134-62). Demand increased to higher than the facility's capacity, so the world's first commercial reverse osmosis plant was built (UCLA website http://www.engineer.ucla.edu/explore/history/major-research-highlights/first-demonstration-of-reverse-osmosis) and operated between 1965 and 1969 (Davis et al 1981). Coalinga now receives surface water from the US Bureau of Reclamation.

The first ocean desalination facility in San Diego was constructed in 1962 but intake issues involving kelp and sea grass caused operational challenges (DWR 134-62). The US Navy also began early California desalination operations and research at Port Hueneme (DWR 134-62).

In addition to Morro Bay and Moss Landing, desalination for power plant operation was implemented in 1960 at Southern California Edison Mandalay steam station (now Reliant Energy Mandalay), in Ventura County and later at the Contra Costa Power Plant on the San Joaquin River in Contra Costa County (DWR 134-62).

In the 1970s and 1980s, DWR tested the feasibility of desalinating agricultural drain water to address San Joaquin Valley drainage issues. Reverse osmosis testing facilities were constructed in Firebaugh and Los Banos. These projects assessed biofouling issues and implementation requirements. Ultimately, because of Kesterson drainage issues, the project was discontinued in 1989.

In the 1970s and 1980s, several communities completed potable water desalination facilities, but for various reasons, each of those projects only operated briefly. Decommissioned or non-operational facilities are or were in San Simeon and Santa Barbara. Marina Coast Water District has a standby desalination facility. Reasons cited for ceasing desalination include operational expense and challenges, availability of less expensive supply, and end-of-drought conditions.

San Simeon State Park received desalinated water for a brief time in the early 1990s. An existing desalination facility was moved from the Central Valley to San Simeon to support park water supply shortages. The facility has since been removed.

In the 1990s, several communities constructed brackish groundwater desalination facilities. The City of Tustin completed its groundwater desalter in 1989. Over a dozen other facilities were constructed and began operation by the end of the decade. These facilities were primarily located in the near-coastal and inland areas of the greater Los Angeles.

Present/Current Desalinated Water Use in California

Desalination is currently an important water supply for areas throughout California. Existing projects are identified in Table 10-6 and are shown in Figure 10-5. Desalination of brackish groundwater and sea water are discussed separately below.

Current Brackish Groundwater Desalination

Groundwater desalting plants are generally designed to reclaim groundwater of impaired use and are located in urban areas from the San Francisco Bay Area to San Diego. Currently, there are at least 20 operating groundwater desalting plants, 19 of which are located in southern California. Plant capacities range from 500,000 gallons to 10 million gallons per day (mgd) (11,200 AFY). Up to an additional 20 plant expansions or new facilities are planned to be constructed before 2040.

Inflow groundwater quality ranges significantly depending on the project. The primary constituent targeted for removal by these projects is usually TDS but nitrate removal may also be an objective. One of the key constraints for groundwater desalination is brine disposal. Existing facilities are either located near a brackish or saline water body or near a brine disposal line, such as the Inland Empire Brine Line (also known as the Santa Ana Regional Interceptor – SARI). These regional interceptors enable sustainable disposal of brine wastes. Several additional lines are planned for the southern California area; constructing them will be a key component of the expansion of brackish groundwater desalination.

As groundwater desalination expands in the future, groundwater overdraft issues will be an integral consideration. At this time, the majority of groundwater desalination occurs in basins with some degree of groundwater management or adjudication. This enables groundwater desalination to be strongly linked to other groundwater uses and recharge activities, IRWM, and local supply.

Current Sea Water Desalination

Most of the desalination facilities using sea water as source water currently operating in California are for non-potable uses. Both potable and non-potable sea water existing facilities are shown in Figure 10-5 because these facilities provide context for uses and contribute to understanding overall water supply in California.

Only four facilities (Morro Bay, Avalon, Nicholas Island, and Sand City) are currently used routinely for potable supply. Because of operating expenses, potable sea water desalination facilities often operate intermittently. Morro Bay can operate using either groundwater or sea water as the feed water.

Several communities in California are grappling with whether to invest in sea water desalination for routine or drought water supply. Projects include facilities to be constructed with both public and private funds. The issues being considered vary significantly, but the common issue is the contentiousness of the discussions. In San Diego County at Carlsbad, a 50mgd seawater desalination plant with RO technology is currently under construction.

PLACEHOLDER Figure 10-5 Existing California Brackish and Sea Water Desalination Facilities

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Legal and Regulatory Framework of Desalination in California

General

Water supply projects utilizing desalination technologies are subject to State statutes and regulations as well as local laws. Over [XX] permitting authorities have been indentified for the planning, management, and operation of desalination facilities.

Planning and Management of Water Resources

A general policy framework for desalination in California is set forth in the Cobey-Porter Saline Water Conversion Law (Water Code §§ 12946 – 12949.6). The people of the state have a primary interest in development of economical desalination processes that could:

- Eliminate the necessity for additional facilities to transport water over long distances, or supplement the services provided by long-distance facilities.
- Provide a direct and easily managed water supply to assist in meeting the growing water requirements of the State.

DWR is directed to find economic and efficient methods of desalination so that desalted water (e.g., drinking water or other water) may be made available to help meet the growing water requirements of the State.

Protecting Water Quality

The brackish and sea water environments are important to preserve and protect. Utilizing desalination techniques requires compliance with State and federal laws governing water quality.

The federal Clean Water Act established a permit system known as the National Pollutant Discharge Elimination System (NPDES) to regulate point sources of discharges into navigable waters of the United States.

The Porter-Cologne Water Quality Control Act is California's comprehensive water quality control law and is a complete regulatory program designed to protect water quality and beneficial uses of the state's water. This act requires the adoption of water quality control plans by the State Water Resources Control Board and the State's nine Regional Water Quality Control Boards (RWQCBs) for watersheds within their regions. These plans designate beneficial uses for each surface and ground water body of the State, water quality objectives to protect these uses, and implementation measures.

The Porter-Cologne Act also establishes a permitting system for waste discharge requirements for point and nonpoint sources of discharges to both surface water and land. The U.S. Environmental Protection Agency has delegated authority to the RWCQBs to issue NPDES permits. These permits are issued in tandem with waste discharge requirements. These permits are required for disposal of brine from desalination facilities. The permits incorporate provisions in the water quality control plans, including protections of the brackish and sea water aquatic ecosystems.

Protecting Drinking Water

Safe drinking water is dependent upon protection of the surface and ground water sources of water from pollution as well as maintaining appropriate water treatment to remove harmful chemicals and pathogens before they can enter into the drinking water supply. The primary agency responsible for regulating drinking water systems is the California Department of Public Health (CDPH). However, the SWRCB and the RWQCBs also have an important role.

The federal Safe Drinking Water Act (SDWA) directed the U.S. EPA to set national standards for drinking water quality. It required the EPA to set maximum contaminant levels for a wide variety of constituents. Local water suppliers are required to monitor their water supplies to assure that regulatory standards are not exceeded. The finished water of a municipal desalination facility must meet these standards. Under the SDWA, the State is required to develop a comprehensive Source Water Assessment Program that will identify the areas that are used to supply public drinking water systems, inventory possible contaminating activities, assess water system susceptibility to contamination, and inform the public of the results. This assessment could include surface and subsurface sources for desalination projects.

The CDPH has primary responsibility for implementing the SDWA in California as well as provisions in State law. In 1999 CDPH issued the “Drinking Water Source Assessment and Protection (DWSAP) Program” (revised in 2000). The program is primarily voluntary on the part of water agencies to perform source water assessments. As of 2003 between 82 and 97 percent of surface and ground water sources were covered by assessments. There is no requirement that these assessments be updated. The implementation measures to protect source waters are a mix of voluntary and mandatory actions by local water and land use planning agencies and the regulatory programs of county health departments, CDPH, SWRCB, and the RWQCBs.

The primary safeguard against pollution of source waters is the RWQCBs through their permitting systems for discharges and other nonpoint source control programs. These permits are based on protecting the beneficial uses of water bodies specified in water quality control plans. By default, bodies of surface and ground water in California are considered suitable or potentially suitable for municipal or domestic water supply and are classified as MUN in water quality control plans (SWRCB, Resolution No. 88-63). One of exceptions is water bodies where the TDS exceeds 3,000 mg/L and it is not reasonably expected by RWQCBs to supply a public water system. However, RWQCBs are to assure that the beneficial uses of municipal or domestic supply are designated for protection wherever those uses are presently being attained. With a few exceptions, RWQCBs have not designated for protection brackish groundwater or ocean water sources currently being treated with desalination for municipal water supply.

Environmental Laws for Protecting Resources

The California Environmental Quality Act (CEQA) is a California statute passed in 1970 to institute a statewide policy of environmental protection. CEQA directly followed the National Environmental Policy Act (NEPA) instituted by the U.S. federal government. CEQA does not directly regulate land uses or other activities. CEQA requires State and local agencies within California to adopt and follow protocols of analysis and public disclosure of environmental impacts of proposed projects and carry out all feasible measures to mitigate those impacts. CEQA makes environmental protection a mandatory part of every California State and local agency's decision making process.

Applying CEQA requirements equally among water supply alternatives (e.g., fresh, brackish, sea, and direct/indirect recycling) is essential for determining the best water supply project to implement.

Protecting Endangered Species and Habitats

There are federal and State laws to protect endangered species of wildlife and their habitats. These laws are encountered with desalination intakes and brine discharges.

Federal Endangered Species Act (ESA). The ESA is designed to preserve endangered and threatened species by protecting individuals of the species and their habitat and by implementing measures that promote their recovery. Under the federal ESA, an endangered species is one that is in danger of extinction in all or a significant part of its range, and a threatened species is one that is likely to become endangered in the near future. The ESA sets forth a procedure for listing species as threatened or endangered. Final listing decisions are made by U.S. Fish and Wildlife Service (USFWS) or National Marine Fisheries Service (NMFS).

Federal agencies, in consultation with the USFWS or NMFS, must ensure that their actions do not jeopardize the continued existence of the species or habitat critical for the survival of that species. The federal wildlife agencies are required to provide an opinion as to whether the federal action would jeopardize the species. The opinion must include reasonable and prudent alternatives to the action that would avoid jeopardizing the species' existence. Federal actions, including issuance of federal permits, such as the dredge and fill permit required under Section 404 of the federal Clean Water Act, trigger federal ESA requirements that the project proponent demonstrate that there is no feasible alternative consistent with the project goals that would not affect listed species. Mitigation is required if impacts on threatened or endangered species cannot be avoided.

The federal ESA prohibits the "take" of endangered species and threatened species for which protective regulations have been adopted. Take has been broadly defined to include actions that harm or harass listed species or that cause a significant loss of their habitat. State agencies and private parties are generally required to obtain a permit from the USFWS or NMFS under Section 10(a) of the ESA before carrying out activities that may incidentally result in taking listed species. The permit normally contains conditions to avoid taking listed species and to compensate for habitat adversely impacted by the activities.

California Endangered Species Act (CESA). The California Endangered Species Act is similar to the federal ESA. Listing decisions are made by the California Fish and Game Commission. All State lead agencies are required to consult with the Department of Fish and Game about projects that impact State listed species. DFG is required to render an opinion as to whether the proposed project jeopardizes a listed species and to offer alternatives to avoid jeopardy. State agencies must adopt reasonable alternatives unless there are overriding social or economic conditions that make such alternatives infeasible. For projects causing incidental take, DFG is required to specify reasonable and prudent measures to minimize take. Any take that results from activities that are carried out in compliance with these measures is not prohibited.

Many California species are both federally listed and State listed. CESA directs DFG to coordinate with the USFWS and NMFS in the consultation process so that consistent and compatible opinions or findings can be adopted by both federal and State agencies.

Regulatory and Permitting Agencies

Most of the primary agencies that exercise regulatory and permitting authority with regard to water supply facility planning, construction, and operation, and that could exercise authority for construction and operation of desalination facilities in California, are listed in Table 10-5 below with their current primary role. There is a current effort within the State agencies to improve the permitting process of projects along the California coast and there is a recognized need by all stakeholders to formally adopt a coordinated permitting process.

PLACEHOLDER Table10-5 Regulatory Agencies for Municipal Desalination Projects

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

[The California Coastal Commission and the State Lands Commission roles will be discussed.]

Regulations for Water Use Efficiency

The State Urban Water Management Planning Act requires urban water suppliers that serve more than 3,000 customers or more than 3,000 acre-feet per year to prepare and adopt urban management water plans. The plans must contain several specified elements, including identifying feasible desalination water supply alternatives. The act also requires water suppliers to review and update their plans at least once every five years.

Potential Benefits

General

Desalination is becoming increasingly important in certain locations and circumstances throughout California. Coastal and inland communities are piloting and implementing full-scale brackish and sea water desalination facilities to meet water demands for:

- Existing and anticipated population growth.
- Replacing imported water deliveries (State Water Project and Colorado River).
- Increasing reliability for periods of local drought.
- Safeguarding against disaster scenarios (risk reduction) which could affect imported or natural fresh water deliveries (e.g., Delta levee failure, out-of-region and statewide droughts, and earthquake damage to conveyance systems).
- Fulfilling restoration and sustainability commitments for the natural environment. Restoration or protection of freshwater habitat may diminish availability of freshwater that is currently being used. Desalination at the place of use may offset freshwater that is necessary for restoration or sustainability commitments.
- Cleaning up and remediating groundwater basins.
- Implementing strategic planning initiatives for climate change adaptation.
- Protecting all water sources (fresh and saline) from degradation.
- Bringing better quality and quantity of water to disadvantaged communities, as a way to practice environmental justice.

The list above is not intended to be exhaustive, but it highlights the multiple potential benefits that may be achieved by building a desalination facility.

1. [Brief discussion on--existing and anticipated population growth]
2. [Brief discussion on--replacing imported water deliveries (State Water Project and Colorado River)]
3. [Brief discussion on--increasing reliability for periods of local drought]
4. [Brief discussion on--safeguarding against disaster scenarios (risk reduction) which could affect imported or natural fresh water deliveries (e.g., Delta levee failure, out-of-region and statewide droughts, and earthquake damage to conveyance systems)]
5. [Brief discussion on --fulfilling restoration and sustainability commitments for the natural environment]

6. [Brief discussion on--implementing strategic planning initiatives for climate change adaptation,
7. [[Brief discussion on--protecting all water sources (fresh and saline) from degradation]
8. [Brief discussion on--practicing environmental justice.]

[The paragraphs below will be merged into these topics]

Desalination provides a means to protect and preserve current drinking water supplies (ground water and surface water) by relieving groundwater over-drafting, stemming seawater intrusion, and maintaining surface flows for the environment. When addressing projected climate change impacts, the inclusion of saline water bodies as drinking water sources is likely essential.

In times of water scarcity, population growth, and climate change, water resources are expected to become more stressed. Traditional water supply management methods such as surface water storage, groundwater extraction, and inter-basin water transfer may not be sufficient to meet increasing water demand. Given that conventional water sources are often limited by overdraft, depletion, pollution, and environmental requirements, desalination can be a reliable water supply alternative and a part of the solution for meeting current and future water needs.

Through desalination, even small scale desalination facilities can serve to meet sustainability and reliability objectives for municipal water supply by providing an emergency water supply. Such facilities as mobile water treatment units including those that can desalt sea or other saline waters can provide emergency potable water supply for towns and communities during droughts, emergencies, or unplanned disruption of their water supplies. These mobile water desalination units are generally reverse osmosis technology that can be truck-mounted or air-lifted and quickly and easily deployed to the water-short areas. Unlike permanent desalination plants, temporary mobile units can be commissioned, installed, and put into production in a short period of time provided environmental and other concerns are addressed. They can also be quickly moved or decommissioned as necessary. [Reference to be added]

[Required coordination of contingency plans involving desalination?]

Potential Costs

General

The cost of desalination depends on numerous factors that are project-specific. When planning desalination projects, it is important that cost estimates take into account the costs of concentrate management and intake systems, including environmental and permitting costs, process costs (i.e., costs of pre-treatment, post-treatment, and main desalting process) and distribution costs.

The cost and affordability of desalination is influenced by the type of source water, the available concentrate disposal options, the proximity to distribution systems, and the availability and cost of power. The higher costs of desalting may, in some cases, be offset by the benefits of increased water supply reliability or the environmental benefits from substituting desalination for a water supply with higher environmental costs. When comparing the cost and impacts of desalination as a water supply option, it is important to compare it to the development of other new treated water supply options.

Technological advances in desalination in the last 20 years have significantly reduced the cost of desalinated water to levels that are comparable, and in some instances competitive, with other alternatives for acquiring new water supplies. Membrane technologies in the form of reverse osmosis (RO) have the most significant improvement. Continuing improvements in system design, membrane technology and energy efficiency and recovery have helped increase efficiency and reduce costs and energy demand. The RO process has been proven to produce high quality drinking water throughout the world for decades.

[Cost data from sources such as the Pacific Institute and WateReuse Association reports will likely be added.]

Major Implementation Issues

General

Following is a list of major factors influencing desalination as a viable resource management strategy:

- Permitting and regulatory framework
- Energy Use and Sources
- Climate Change
- Funding
- Concentrate (Brine) Management
- Planning and Growth
- California's Ocean and Freshwater Ecosystem
- Contamination from urban runoff and microbial content (take-up in ocean intakes)

A brief description of these major factors is provided in the next sections.

Permitting and Regulatory Framework

Two permitting and regulatory issues have been identified: coordination of permitting and protection of source waters used for municipal drinking water. As described in the "Legal and Regulatory Framework of Desalination in California" section above, there are over 35 federal, State, and local agencies that have some regulatory or permitting authority over desalination projects. While any single project may not have to encounter all of these, the regulatory process can be formidable and lengthy. A need for coordination between agencies has been indentified (DWR 2003, Water Desalination: Findings and Recommendations, Sacramento, California, October 2003).

One effort to improve coordination is the creation of the State agency Desalination Interagency Workgroup in 2012. It has been proposed that the State permitting agencies establish an agency priority sequence for permit reviews to improve coordination at the project level.

A key element in the protection of sources of drinking water is the designation of water bodies for this beneficial use in water quality control plans adopted by the RWQCBs and SWRCB. As described in the "Legal and Regulatory Framework of Desalination in California" section, brackish and seawater sources being used for municipal drinking water after desalination are not designated for this beneficial use. Desalination is very effective in removing constituents in water that could be harmful to human health; however, desalination does not remove all chemicals, including some chemicals with known health effects. There is a general concern in water quality management about the thousands of manufactured chemicals introduced into the environment with little or no testing for human or environmental effects. These chemicals are commonly referred to as chemicals of emerging concern (CEC). A regulatory strategy has not been developed to prevent potentially harmful CECs or other chemicals of known health effects from occurring in brackish or seawater sources of drinking water. Source water assessments can be used to identify zones of protection for saline waters used for drinking water, assess the potential contaminant activities, and identify chemicals that cannot be normally expected to be removed by desalination. Water quality control plans can designate zones in saline waters for protection as sources of drinking water after desalination and include appropriate regulatory measures, such as water quality objectives or implementation programs, to provide reasonable protection for this use.

Energy Use and Sources

Energy use is a significant factor in water desalination projects for reasons of costs and environmental impacts of energy generation. Each of the elements in a desalination system, as shown in Figure 10-2, entails energy use, but the most significant energy use is in the desalination treatment process. Generally, the energy requirement of RO desalination is a direct function of the salinity and temperature of the feedwater source. Given similar operating conditions and treatment plant parameters, brackish water desalination is usually less energy intensive, and hence less costly, than seawater desalination. Several summary reports on desalination and energy intensity of water supply and treatment systems have been published that report data on the energy intensity of desalination processes. Drawing from an array of studies (CEC, 2005; CPUC, 2010; Wilkinson, 2007; Pacific Institute, 2012; WeSim, 2012; and Water ReUse Foundation, 2011) energy intensity for sea water desalination ranges between 2,970 kWh/AF to 5,920 kWh/AF and between 978 kWh/AF and 2,704 kWh/AF for brackish water desalination.

In order to compare the energy intensity of desalinated water supplies with the energy intensity of other water supplies provided in each regional report, a factor for water treatment would have to be added to the energy intensities of “raw water” provided in the regional reports. The energy of conventional water treatment is typically between 50 kWh/AF and 2000 kWh/AF depending on the capacity of the treatment plant and the quality of incoming raw water (WeSim, 2012; Water ReUse Foundation, 2011).

For a seawater desalination RO facility, 28 percent to 50 percent of total annual costs, including annual capital recovery costs, are devoted to energy consumption (Water ReUse Foundation, 2011). However, improvements in RO membranes and the incorporation of energy recovery devices in treatment facilities have resulted in reduced energy needs for new facilities compared to older projects. While research continues, it is not expected that further major reductions will occur in the near term. Because of the high energy requirements for desalination it is especially important to look at the sources of power used to operate plants. Although there has been an overall emphasis on expanding reliance on sustainable/renewable energy sources within California, fossil fuel-based power plants continue to be a major source of energy, about 62% of total in-state electricity generation. Significant improvements in energy generation technology have reduced the environmental impacts associated with energy generation, nonetheless, energy generation (including exploration, extraction, and conversion to electricity) continues to result in significant environmental impacts. Air pollution including greenhouse gases, groundwater pollution, water use, and despoiling of scenic views and wildlife habitat are major concerns associated with new and existing energy generation. Many of these concerns do not only apply to just fossil energy sources, but also to renewable power.

Aside from drawing electricity from a power grid to operate desalination, there are proposed concepts to incorporate renewable energy generation directly into a desalination facility. In some proposals, seawater desalination can take advantage of its proximity to natural energy within the ocean environment. A desalination plant that would be driven by wave energy is planned in Australia with government funding (add reference). In addition, research is being conducted on two concepts funded by the U.S. Environmental Protection Agency: the microbial desalination fuel cell and desalination with a solar evaporation array [Add references].

Climate Change

General

As water resource planners and managers move to develop water supplies, they will need to address potential climate change impacts. Climate change projections include warmer air temperatures, diminishing snowpack, precipitation uncertainty, increased evaporation, prolonged droughts, and sea level rise. These anticipated changes could further reduce water supply in many regions including those that are already experiencing difficulty meeting current water demands. Climate change impacts will put additional stress on aging freshwater collection, storage, and conveyance infrastructure reducing the capacity to provide a stable source of drinking water.

Loss of snowpack, prolonged droughts, and sea level rise will likely be some of the most critical impacts for California water managers who may consider desalination in their regional water management portfolios. DWR projects that the Sierra snowpack will experience a 25 to 40 percent reduction from its historic average by 2050, limiting the amount of water that can be supplied during the summer and fall months. Prolonged droughts, with changes in precipitation and runoff patterns will likely impact communities that rely upon surface water deliveries making them more dependent on groundwater sources. Sea level rise could increase salt water intrusion to coastal freshwater aquifers resulting in brackish waters that would require treatment to attain drinking water standards. Whether an overall increase or decrease in precipitation, runoff, or capture occurs due to climate change, initial estimates of watershed models are that increases in temperature and consequent increases in evapotranspiration will cause a higher water demand.

Adaptation

In some regions that are already experiencing difficulty meeting current water demands, a portion of the water supply is already being supplied by the desalting process. As the impacts of climate change continue to intensify, desalination may become a more attractive adaptive strategy. Desalination provides a water supply that remains robust even during extreme drought periods; desalination capacity will not be affected by rising sea levels, decreased exports from the Sacramento-San Joaquin Delta, or changes in snowpack runoff. Therefore, desalination is an adaptation strategy to improve the resiliency and reliability of a region’s water supply even in the face of uncertain future climate conditions.

Mitigation

Because of the higher energy intensity of desalination (when compared to most alternative water supplies) energy use and associated greenhouse gas emissions from desalination pose a major concern. While desalination may be used to increase water supplies and provide a climate resilient and robust water supply, operation of desalination facilities may have associated substantial GHG emissions depending on the type of energy used to operate them; some energy sources contribute to existing atmospheric GHG concentrations and lead to larger future climate changes. Potential mitigation opportunities include reduced energy consumption by increasing operational and process efficiencies and coupling or dedicating renewable/sustainable energy sources not generating GHGs to desalination facilities.

The energy factors provided above in the Energy Use and Sources section can be converted to GHG emissions by using a GHG emission factor for the region or the energy utility that would provide power to for desalination. The California region (CAMX) average GHG emissions rate for electricity is 0.300 metric tons CO2e/MWh. Emissions rates for specific utilities service areas and other states can be found at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

While desalination is a proven technology, in most cases, its energy requirements are higher than levels necessary for importing and treating water to the region or using local groundwater and surface water sources. Brackish water desalination is comparable in energy intensity with recycled and imported water supplies, while sea water desalination is considerably more energy intensive than most other water supply options. As an energy intensive process, desalination has the potential to counteract the GHG reduction goals of California if fossil fuel powered plants are used as a primary energy source. However, desalination operations can take measures to optimize efficiency, purchase renewable energy, minimize GHGs on-site, and mitigate for emissions off-site to reduce their overall carbon footprint.

California's Ocean and Freshwater Ecosystem

A primary concern associated with coastal desalination plants is the impact of feed water intake on aquatic life. Surface intakes of seawater result in impingement and entrainment of marine organisms. This impact can be avoided by adopting subterranean intakes (e.g., beach wells and under ocean bed intakes) wherever feasible. Proper design of open water intakes can significantly reduce impacts. It is important to have a strong regulatory structure to ensure protection of the ocean and other aquatic environments.

Restrictions put in place to protect fish and wildlife within the inland watershed zone may prevent a community from meeting its freshwater supply from either ground or surface water within the affected watershed zone. Seawater desalination may be the most sustainable option to meet water demands while protecting fresh and brackish water environments.

In the past, seawater desalination has been able to gain cost efficiency by sharing intake and discharge structures with coastal power plants. This option, however, may be diminishing. To reduce the harmful effects associated with cooling water intake structures on marine and estuarine life, the State water Resources Control Board has adopted a policy preventing any new once-through cooling power plants [citation for Once-Through Cooling Policy].

Funding

General (Past, Present, Future)

From the world, national, and State, and local perspective, funding sources have fluctuated since the 1950's. Desalination technology is being used in over 140 countries with investments in desalination research and development likely out pacing the USA (NAP, 2008).

U.S. national desalination research and development efforts are funded through at least nine federal agencies and laboratories, each with their own research objectives and priorities. The majority of federal desalination research and development funding also comes from congressional earmarks, which limit the ability to develop a steady research program (NAP, 2008, Page 30).

Financial aid and other funding opportunities are critical to the progression of Desal-RMS at the national, State, regional, and local levels. The recent successful progression of desalination from a cost prohibitive alternative to the alternative of choice is attributed, in part, to funding.

The funding mechanisms available for the progression of desalination in California are grants, loans, and rebates. The California legislature emphasized the importance of water desalination in 2003 with the passages of Assembly Bill 314, which declared that it is the policy of the State that desalination projects developed by or for public water entities be given the same opportunities for State assistance and funding as other water supply and reliability projects.

Grants (Past, Present, Future)

In November 2002, California voters passed Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002. Chapter 6 of that proposition authorized $50 million in grants for brackish water and ocean water related funding. The grant program aimed to assist local public agencies with the development of new local potable water supplies through the construction of feasible brackish water and ocean water desalination projects and advancement of water desalination technology and its use by means of feasibility studies, research and development, and pilot and demonstration projects. Two cycles of funding under this grant program were conducted during 2005 and 2006, competitively awarded approximately $46.25 million in grants to 48 projects including 7 construction projects, 14 research and development projects, 15 pilots and demonstrations, and 12 feasibility studies.

This program has resulted in approximately 30 thousand acre-feet of water produced annually from the five completed construction projects. A third round of funding is underway and slotted for the 2013-2014 fiscal year with approximately $8.7 million of unused grant funds.

Another source of funding for desalination is the for integrated regional water management (IRWM) Grant Program. In 2002, Senate Bill 1672 created the Integrated Regional Water Management Act to encourage local agencies to work cooperatively to manage local and imported water supplies to improve the quality, quantity, and reliability. This water management style engages diverse stakeholders with a multitude of perspectives to arrive at multibenefit projects (including desalination projects) to meet several goals and objectives in a more cost effective manner than each entity acting on its own. Two propositions contained bonds to fund IRWM projects: Proposition 50 in 2002 and Proposition 84 in 2006. This program has resulted in over 10 desalination projects. IRWM implementation grants are planned for the 2014-2015 fiscal year pending the legislative appropriation of bond funds. Final program guidelines and proposal solicitation are projected to be released in the fall of 2014 with the applications due winter 2014/2015.

Loans (Past, Present, Future)

[General information concerning grant loans for desalination will be provided in this section.]

Rebates (Past, Present, Future)

[General information concerning rebates for desalination projects will be provided followed. As an example, there are rebate programs offered by the Metropolitan Water Districts (MWD) for desalination.]

Other (Past, Present, Future)

[General information concerning “other” as required rebates for desalination projects in this section. This subheading may not be needed. Readers should provide information to DWR if they are aware of funding not fitting into the previous subsections for inclusion here.]

Concentrate (Brine) Management

The desalination process produces a salty concentrate (brine) that must be properly managed. This brine must be handled in an environmentally safe and sustainable manner in accordance with regulations. The quantity and salinity of the concentrate varies with the type of technologies employed in operating the plant.

Brine management alternatives for disposal include but are not limited to processes utilizing:

- Discharge to separate permitted wastewater collection and treatment systems.
- Discharge and dispersion to water bodies such as oceans and bays.
- Discharge by land application usually involving further solids disposal after evaporation of liquid portion of discharge.
- Discharge to deep groundwater wells through an injection process.
- Disposal processes using further treatment trains resulting in what is termed “zero liquid discharge” disposal whereby the solids produced have reuse potential and thus are not sent to waste and nearly all water is recovered.

It is more likely that brackish water plants in California discharge their concentrate to municipal wastewater treatment systems where it is incorporated, treated, and disposed of with other municipal wastewater. For brackish water desalination plants, this type of concentrate management is likely to continue where the wastewater treatment system capacity is adequate. Plant locations where suitable wastewater collection and treatment systems are not available or locations without a discharge to the ocean may be limited by the type of discharge options available. Seawater desalination produces a concentrate approximately twice as salty as seawater. In addition, residuals of other treatment chemicals may also be in the concentrate of brackish and seawater. Some plants currently being planned will use existing power plant or wastewater plant outfall systems to take advantage of dilution and mixing prior to discharge to the ocean or adjacent water bodies. The availability of power plant cooling systems to dilute the concentrate prior to discharge to the ocean will also be affected by the future of coastal power plants as discussed in the California's Ocean and Freshwater Ecosystem Section. On the other hand, co-locating concentrate discharge with wastewater effluent outfall might have some environmental benefits to the extent that the concentrate from the desalination plant would increase the salinity of the wastewater effluent to levels that are comparable or closer to that of seawater.

Brine discharges from desalination facilities are regulated by the State Water Resources Control Board through the issuance of a National Pollutant Discharge Elimination System (NPDES) permit that contains conditions protective of aquatic life. Concentrate management requires integration with other plans adopted by the State such as the Ocean Plan and Enclosed Bays, Estuaries and Inland Surface Waters Plan. The Ocean Plan does not currently have an objective for elevated salinity levels in the ocean, nor does it describe how brine discharges are to be regulated and controlled, leading to permitting uncertainty. The Ocean Plan also does not address possible impacts to marine life from intakes for desalination facilities. An Ocean Plan amendment is currently underway as this chapter was drafted and is envisioned to have the following components: a "narrative" objective for salinity, provisions to minimize impacts to marine life from desalination plant intakes, and implementation provisions. State Water Board staff anticipates that the Ocean Plan amendment will be completed by late 2013.

Planning and Growth

There are many factors to consider before deciding whether to implement a water desalination project. Desalination should be analyzed in comparison with other alternatives that could achieve the same project objectives. In the context of this resource management strategy, obtaining a municipal water supply would be a primary objective. There are established feasibility criteria that are applied in water resources planning:

- Ability to meet project objectives.
- Technical feasibility.
- Economic justification.
- Financial feasibility.
- Environmental feasibility.
- Institutional feasibility.
- Social impacts.

As with any water resources project, desalination cannot be evaluated on the basis of any single criterion. Water supply alternatives rarely include an outstanding alternative that meets all of a community's vision for the future and the needs and goals to achieve that vision. All alternatives, including desalination, needed to be evaluated together applying the evaluation criteria listed above.

Drawing on the work of the California Water Desalination Task Force, which was convened in 2003, DWR published the *California Desalination Planning Handbook* (DWR, 2008). This handbook is a valuable resource for project proponents and communities. It provides a planning framework for developing, where appropriate, economically and environmentally acceptable desalination facilities in California. The planning process outlined in the handbook is intended to identify and address citing, regulatory, technical, environmental and other issues, which should be considered in determining whether and how to proceed with a desalination project.

There are major issues facing desalination, as described in other sections, including cost, environmental impacts, greenhouse gas emissions, and growth inducement. A methodical planning process with community involvement is the best procedure to minimize negative impacts and to weigh these impacts against those of other water supply options and the supply reliability and other benefits of desalination. Even the presence of unavoidable adverse impacts may be acceptable. As stated in the regulations implementing CEQA:

> "CEQA requires the decision-making agency to balance, as applicable, the economic, legal, social, technological, or other benefits, including region-wide or statewide environmental benefits, of a proposed project against its unavoidable environmental risks when determining whether to approve the project. If the specific economic, legal, social, technological, or other benefits, including region-wide or statewide environmental benefits, of a proposal project outweigh the unavoidable adverse environmental effects, the adverse environmental effects may be considered "acceptable."" (California Code of Regulations, Title 14, Division 6, Chapter 3, section 15093(a))

One of the issues has been the assertion that desalination is "growth-inducing." Any water supply or water management alternative, including water conservation that augments or frees up water supply to accommodate new water demands has the same potentially growth-inducing impact. A community's vision for population growth and land development ideally should be resolved in a broader context of community planning, such as county general plans, not water supply planning. CEQA guidelines require that growth-inducing impacts of a proposed project be discussed in environmental documents. However, as stated in the guidelines, "It must not be assumed that growth in any area is necessarily beneficial, detrimental, or of little significance to the environment." (California Code of Regulations, Title 14, section 15126.2(d))

The goal of a the water resources planner is to meet the needs of the community for a reliable water supply now and in the future as the public has envisioned future land use and population. Desalination is part of the portfolio of potential supplies that should be considered. An analysis of desalination is required as part of urban water management plans complying with the Urban Water Management Planning Act (Water Code section 10631) and integrated regional water management plans submitted as part of the Integrated Regional Water Management Grant Program.

Recommendations

General

Desalination of sea and brackish water is a proven technique to augment water supplies in a balanced water supply portfolio. Treatment of brackish groundwater for beneficial use is a common practice in California and in some instances may approach conventional treatment status. Small scale seawater desalination facilities, less than 5 million gallons per day, have been built but as of 2013, desalination facilities have not become an established method to meet municipal water demands.

Desalination, particularly of sea water, has been a challenge. If desalination is to be an appropriate and successfully implemented component of California's water supply, certain constraints need to be agreed upon and certain actions need to take place in the planning, regulatory, and scientific arenas.

Nevertheless, sea and brackish surface waters are potential water supplies in many parts of California as they are throughout the world, and water supply planners in California are continuing to include desalination of saline water to diversify water supply portfolios.

The following general recommendations are maintained for proper implementation of Desal-RMS.

Policy

1. The State recognizes that desalination is an important water supply alternative and, where economically, socially and environmentally appropriate, should be part of a balanced water supply portfolio, which includes other alternatives such as conservation and water recycling.
2. Only environmentally sound desalination should be implemented. Regulatory agencies should have a strong regulatory framework with adequate resources to establish technically sound criteria that provide adequate environmental safeguards for water supply projects including desalination.
3. The State recognizes that desalination requires energy to operate and to mitigate the energy needs where economically and environmentally appropriate, project sponsors and water suppliers should consider coupling energy from sustainable sources.

[DWR is considering a policy or specific action level recommendation for establishing a State funding source for desalination implementation and research projects.]

Actions

4. Project sponsors and water suppliers should evaluate desalination techniques, both groundwater and surface waters, alongside and combined with municipal wastewater recycling, including the indirect and direct potable reuse, as a means to meet existing and future water demands. This evaluation will provide a means for communities across the state to make sound choices on water supply options as appropriate through science based decision making for a sustainable future.
5. When planning a water supply project as part of an integrated regional water management plan prepared for State funding, project sponsors and water suppliers shall consider desalination as a strategy to meet the goals and objectives of the region [California Water Code §10530].
6. Desalination should be evaluated using the same well-established planning criteria applied to all water management options, using feasibility criteria such as: water supply need within the context of community and regional planning, technical feasibility, economic feasibility, financial feasibility, environmental feasibility, institutional feasibility, social impacts, and climate change. The California Desalination Planning Handbook published by DWR should be one of the resources used by water supply planners.
7. Project sponsors and water suppliers should evaluate desalination within the context of integrated water management reflecting community and regional needs and priorities with respect to water quality protection, water supply, growth management, brine disposal and economic development. Water management planning has to occur within a wider context of community values and visions for the future. Key stakeholders, the general public, and permitting agencies need to be engaged in the planning process.
8. DWR, in collaboration with regulatory agencies, should lead an effort to create a coordinated streamlined permitting process for desalination projects. Because of the many regulatory agencies involved in desalination of ocean, bay or estuarine waters, a coordinated framework to streamline permitting approvals without weakening environmental and other protections should be explored. Establishing an appropriate sequencing of approval by the various agencies may be

appropriate. The Ocean Protection Council may be appropriate for the role of coordinating regulatory reviews and guiding project sponsors through the regulatory process.

9. Project sponsors and water suppliers should evaluate climate change impacts, primarily due to greenhouse gas generation from energy consumption, for proposed desalination projects within the context of available water supplies alternatives. Note that desalination should not be precluded solely on the basis of energy consumption, because the allocation of energy to meet water supply needs and reliability may be considered of higher social value to a community than other uses of energy.
10. Desalination projects developed by public agencies or utilities regulated by the California Public Utilities Commission should have opportunities for State assistance and funding for water supply and reliability projects.
11. Research and investigations should continue to develop new or improved technologies to advance and refine desalination processes, feedwater intake and concentrate management technologies, energy efficiencies, and the use of alternative and renewable energy sources.
12. DWR should be adequately funded to maintain technical expertise and current data on the status of brackish and seawater desalination in California to support the planning and policy roles of State government and to be an information resource to the public.
13. The SWRCB, in consultation with CDPH and DWR, should develop an effective regulatory framework for protection of saline waters for the beneficial use of municipal drinking water after desalination treatment through Source Water Assessment Plans and Water Quality Control Plans. The framework should provide reasonable protection against CECs or constituents known to be harmful in drinking water which can not reliably, readily, and feasibly be removed with existing technology such as currently employed in RO desalination systems.

Desalination in the CWP

Desalination in the RMS

The following resource management strategies included in this volume have been identified and closely linked to the Desal-RMS and should be investigated accordingly to understand their relationship to meeting regional and local water supply objectives:

- Chapter 11, "Recycled Municipal Water."
- Chapter 24, "Land Use Planning and Management." [this section to be expanded to include the RMS connectedness as needed]
- Chapter 15, "Drinking Water Treatment and Distribution."
- Salts are naturally occurring in the environment, but human activity often increases salinity in water and soil. Because of the negative impacts of salinity on human use or the water environment (fresh and saline), salinity management is a critical resource management strategy (see Chapter 19," Salt and Salinity Management").

References

[Under development, not complete at this time]

References Cited

[References cited (RC) in the CWP Update 2009 have been placed under the "References Cited" subheading below with [2009 RC] preceding the reference. Upon final 2013 draft completion, the

“Additional References” subheading will be used to list any [2009 RC] not specifically requiring citing and relevant references will be given.]

[2009 RC = Reference Cite in 2009 Update; this section is under development and is not complete at this time.]

NAP 2008, Committee on Advancing Desalination Technology ; National Research Council. 2008. Desalination: A National Perspective. Washington (DC): The national Academies Press, ISBN: 0-309-11924-3

[DWR]. California Department of Water Resources. 2003a. California's Groundwater: Bulletin 118 Update 2003. http://www.water.ca.gov/groundwater/bulletin118/bulletin118update2003.cfm.

[CDPH] California Department of Public Health, 2008a, California drinking water-related laws—Drinking water-related regulations, Title 22: California Department of Public Health, accessed March 17, 2010, at http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Lawbook.aspx.

[2009 RC][AB 2717]. An act relating to water conservation. Established the Water Desalination Task Force. Statutes 2002, chapter 957. Water Code, section 12949.6 (2002).

[2009 RC][AB 314]. Desalination. Amendments to the Water Code. Statutes 2003, chapter 206. Water Code, section 12947 (2003).

[2009 RC]Buros, OK. 2000. The abcs of desalting. 2nd ed. Topsfield (MA): International Desalination Association. 32 p. Available at: http://www.elkhornslough.org/desal/ABCs.pdf

[2009 RC]California Coastal Commission. 2004. Seawater desalination and the California Coastal Act. San Francisco: California Coastal Commission. 99 p. Available at: http://www.coastal.ca.gov/energy/14a-3-2004-desalination.pdf

[2009 RC]California Energy Commission. 2005. Integrated energy policy report. Sacramento (CA): California Energy Commission. 182 p. Report No. CEC-100-2005-007. Available at: http://www.energy.ca.gov/2005publications/CEC-100-2005-007/CEC-100-2005-007-CMF.PDF

[2009 RC]Committee on Advancing Desalination Technology; National Research Council. 2008. Desalination: a national perspective. Washington (DC): The National Academies Press. 232 p.

[2009 RC]Committee to Review the Desalination and Water Purification Technology Roadmap; National Research Council. 2004. Review of the desalination and water purification technology roadmap. Washington (DC): The National Academies Press. 64 p.

[2009 RC]Cooley, H; Gleick, PH; Wolff, G. 2006. Desalination, with a grain of salt: a California perspective. Oakland (CA): Pacific Institute for Studies in Development, Environment, and Security. 88 p. Available at: http://www.pacinst.org/reports/desalination/desalination_report.pdf

[2009 RC][DWR]. California Department of Water Resources. 2003. Water desalination - findings and recommendations. Sacramento (CA): California Department of Water Resources. 17 p. Available at: http://www.water.ca.gov/pubs/surfacewater/water_desalination_findings_and_recommendations/findings-recommendations.pdf

[2009 RC][DWR]. California —— University, Center for Collaborative Policy. 2008. California desalination planning handbook. Sacramento (CA): California Department of Water Resources. 77 p. Available at: http://www.water.ca.gov/desalination/pud_pdf/Desal_Handbook.pdf

[2009 RC]Global Water Intelligence. 2006. 19th IDA worldwide desalting plant inventory. Oxford (UK): Media Analytics Ltd.

[2009 RC]Klein, G. 2005. California's water energy relationship. Final staff report. Sacramento (CA): California Energy Commission. 174 p. Report No. CEC-700-2005-011-SF. Available at: http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

[2009 RC][Prop. 50]. Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002. Legislative initiative (AB 1473) approved by voters. Statutes 2002, chapter 618. Water Code, section 79500 et seq. (2002).

[2009 RC]RosTek Associates, Inc.; DSS Consulting, Inc.; Aqua Resources International, Inc.; US Bureau of Reclamation, Water Treatment Engineering and Research Group. 2003. Desalting handbook for planners. 3rd ed. Denver (CO): United States Department of the Interior, Bureau of Reclamation, Water Treatment and Engineering Group. 233 p. Desalination and Water Purification Research and Development Report #72. Available at: http://www.usbr.gov/pmts/water/media/pdfs/report072.pdf

[2009 RC]San Francisco Bay Conservation Development Commission. 2005. Desalination and San Francisco Bay. Staff report. San Francisco (CA): San Francisco Bay Conservation and Development Commission. 31 p. Available at: http://www.bcdc.ca.gov/pdf/planning/reports/desal_and_sf_bay.pdf

[2009 RC]Spiegler, KS; El-Sayed, YM. 1994. A desalination primer: introductory book for students and newcomers to desalination. Santa Maria Imbaro, Italy: Balaban Desalination Publications. 215 p.

[2009 RC]US Bureau of Reclamation; Sandia National Laboratories. 2003. Desalination and water purification technology roadmap. Denver (CO): US Bureau of Reclamation, Water Treatment and Engineering Group. 61 p. Desalination & Water Purification Research & Development Report #95. Available at: http://www.usbr.gov/pmts/water/media/pdfs/report095.pdf

(Draft-Ref#35) National Water Program 2012 Strategy: Response to Climate Change, EPA Public Comment Draft as taken on 08/14/2012 from: http://water.epa.gov/scitech/climatechange/upload/NWP_Draft_Strategy_03-27-2012.pdf

Additional References

[This section is under development and is not complete. This section will included previous references from past Updates and other pertinent references.]

Personal Communications

[This section is under development and is not complete.]

Table 10-1 Measurements of Salinity

Salinity metric	Common Units	Comment
Electrical conductivity (EC)	µS/cm	EC is a measure of the concentration of dissolved ions in water, and is reported in µmhos/cm (micromhos per centimeter) or µS/cm (microsiemens per centimeter). A µmho is equivalent to a µS. EC may also be called specific conductance or specific conductivity of a solution.
Total dissolved solids (TDS)	mg/l or ppm	TDS is a measure of the all the dissolved substances in water and its units are milligrams per liter (mg/l) of solution.
Practical salinity units (PSU)	Unit-less	PSU is approximately equivalent to salinity expressed as parts per thousand (e.g., salt per 1,000 g of solution). Seawater is about 35 PSU. Its actual measurement is a complex procedure. Oceanographers are likely to use PSUs, which is why it is mentioned here.

Table 10-2 Gradation Common Terms

General Water Term	Relative Salinity, mg/L (ppm) TDS
Fresh raw (natural)	Less than 1,000 [a]
Brackish	1,000 to 30,000
Sea	30,000 to 50,000
Hypersaline	Greater than 50,000 or that is found in the sea
Natural brine	Greater than 50,000 to slurries [b]
Discharge brine	1,000 to slurries [c]

[a] Based on community drinking water standards. Salinity target values for municipal drinking water systems using desalination technologies are typically less than 500 ppm TDS.

[b] Also, brines or “salines” naturally derived from groundwater are 100,000 ppm or greater. TDS, NaCl-saturated solutions are approx. 260,000 ppm in concentration.

[c] Discharge brine concentrations vary widely and are dependent upon technologies employed and processes used to discharge brine as a final waste stream to the environment. The concentration of reject water from a desalination facility may be referred to as “brine” but may only be 4,000 mg/l TDS in concentration.

Table 10-3 General Desalination Technology List

Technology	Brief Description
Thermal Distillation	
Technology	**Brief Description**
Multi-Stage Flash evaporation (MSF)	The thermal process by which distillation principles are employed through chambers at slightly different atmospheric pressures to flash liquid water into vapor and immediately condense in adjacent chambers as product water for use. [Reference for additional information needed here]. Large-scale sea water desalination facilities used in many other parts of the world with oil used for energy at less than market prices. Not currently used or proposed in California.
Multi Effect Distillation (MED)	The thermal process by which distillation principles are employed through pipes rather than chambers as in MSF. Once evaporation has occurred, water vapor is condensed within tubes (pipes) rather than chambers. [Reference for additional information needed here]. MED may be more efficient than MSF.
Vapor Compression (VC)	
Membrane Separation	
Technology	**Brief Description**
Electrodialysis (ED)	
Nanofiltration (NF)	
Reverse Osmosis (RO)	Reverse osmosis (RO) is similar to other membrane processes, such as ultrafiltration and nanofiltration, in that water passes through a semi-permeable membrane. However, in the case of RO, the membrane is non-porous. RO involves the use of applied hydraulic pressure to oppose the osmotic pressure across the membrane, forcing the water from the concentrated-solution side to the dilute-solution side. The water dissolves into the membrane, diffuses across, then dissolves out into the permeate.
Forward Osmosis (FO)	Forward osmosis is an intriguing approach that utilizes the conventional osmosis principle. It was considered years ago, but has recently been targeted for development because of improved membrane materials and new techniques including advanced energy recovery equipment.
Microfiltration membranes (MFM)	
Ultrafiltration Membranes (UFM)	
Capacitive Deionization Technology ™	Pilot stage, experimental — an alternative to RO and other desalination technologies.
Ion Exchange	Ion exchange involves the selective removal of charged inorganic species from water using an ion-specific resin. The surface of the ion exchange resin contains charged functional groups that hold ionic species by electrostatic attraction. As water passes by the resin, charged ions on the resin surface are exchanged for the contaminant species in the water. When all of the resin's available exchange sites have been replaced with ions from the feed water, the resin is exhausted and must be regenerated or replaced [EPA-- Drinking Water Health Advisor For Boron]
Other Technologies	

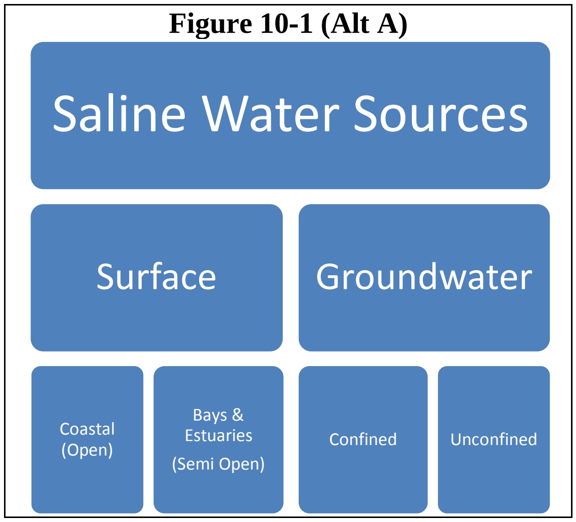
Table 10-4 Brief Description of Membranes

[table to come]

Table 10-5 Regulatory Agencies for Municipal Desalination Projects

Agency or Department	Permit or Approval	Required for
Federal Agencies		
National Marine Sanctuaries	Research Permit or Authorization; Education Permit; Authorization Permit	Review of other State and federal permits (including U.S. Army Corps of Engineers permits, Regional Water Quality Control Board 401, and NPDES permits) with activities/discharges into waters and wetlands.
U.S. Fish and Wildlife Service (USFWS)	Endangered Species Act compliance (ESA Section 7 consultation)	Incidental take of federally listed species.
	Fish and Wildlife Coordination Act (16 U.S.C. 661-667e; the Act of March 10, 1934; ch. 55; 48 stat. 401)	Provide comments to prevent loss of and damage to wildlife resources.
National Oceanic & Atmospheric Administration (NOAA) – Fisheries	Endangered Species Act compliance (ESA Section 7 consultation)	Incidental take of federally listed species.
Army Corps of Engineers (Corps)	Nationwide Permit No. 6, Survey Activities	Survey activities, such as core sampling, seismic exploratory operations, soil surveys, sampling, and historic resources surveys.
	Nationwide Section 404 Permit (CWA, 33 USC 1341)	Discharge of dredge/fill into Waters of the United States, including wetlands.
	Nationwide Permit No. 7, Outfall Structures and Associated Intake Structures	Activities related to the construction or modification of outfall structures and associated intake structures where the effluent is authorized by NPDES, Section 402 of the Clean Water Act.
	Section 10, Rivers and Harbors Act Permit (33 U.S.C. 403)	Activities, including the placement of structures, affecting navigable waters.
U.S. Coast Guard	Federal Consultation	Coastal Commission Coastal Development Permit and ACOE Section 10 Permit.
State Agencies		
State Water Resources Control Board, Regional Water Quality Control Board	General Construction Activity Storm Water Permits.	Storm water discharges associated with construction activity.
	401 Water Quality Certification (CWA Section 401)	Discharge into waters and wetlands (see USACE Section 404 Permit).
	National Pollutant Discharge Elimination System (NPDES) Permit (CWA Section 402)	Discharge into waters and wetlands.
California State Lands Commission	Right-of-Way Permit (Land Use Lease) (California Public Resource Code Section 1900)	Issuance of a grant of right-of-way across state lands.
	Lease Amendment	Modification of Wastewater Outfall lease.
California Department of Fish and Wildlife (CDFW)	Incidental Take Permits (CESA Title 14, Section 783.2)	Activity where a State-listed candidate, threatened, or endangered species under California ESA may be present in the project area and a State agency is acting as lead agency for CEQA compliance.
California Coastal Commission (CCC)	Coastal Development Permit. (Public Resources Code 30000 et seq.)	Development within the Coastal Zone, excluding areas where local jurisdictions have approved Local Coastal Plans in place.
California Department of Public Health (CDPH)	Permit to Operate a Public Water System (California Health and Safety Code Section 116525)	Operation of a public water system. (Amendment only.)
California State Historic Preservation Officer (SHPO)	Section 106 Consultation, National Historic Preservation Act (16 USC 470)	Consult with project applicant, appropriate land management agencies, and others regarding activities potentially affecting cultural resources.

Figure 10-1 Basic Municipal Drinking Water Facility and Source Waters in California



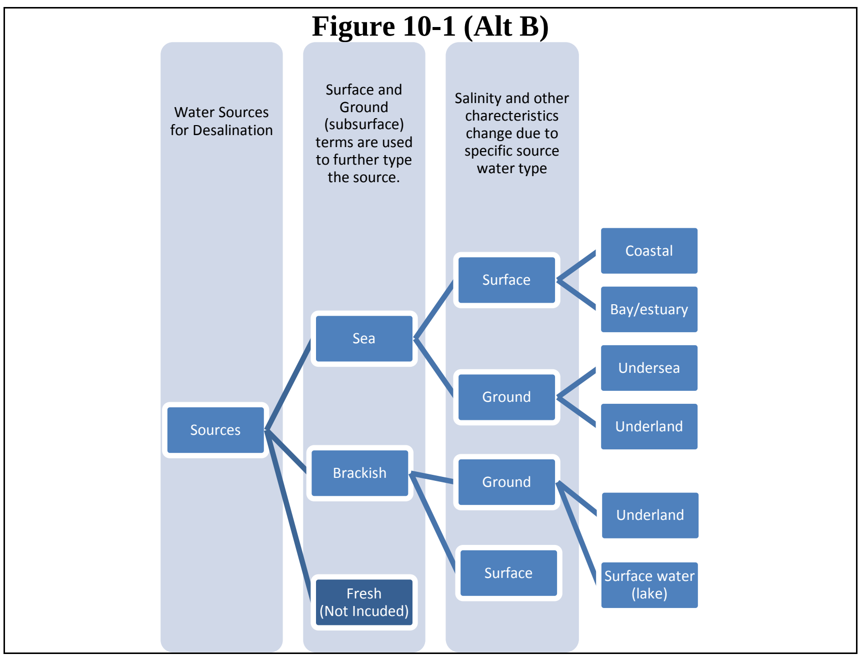
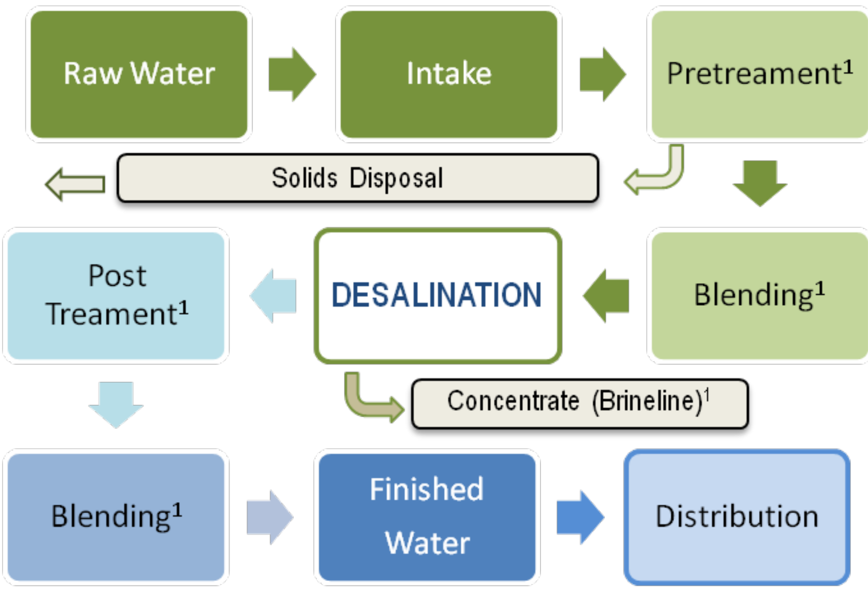


Figure 10-2 General Distinctions for Location

[figure to come]

Figure 10-3 General Desalination System Schematic



1. May not occur at specific desalination facilities.

Figure 10-4 The Filtration Spectrum

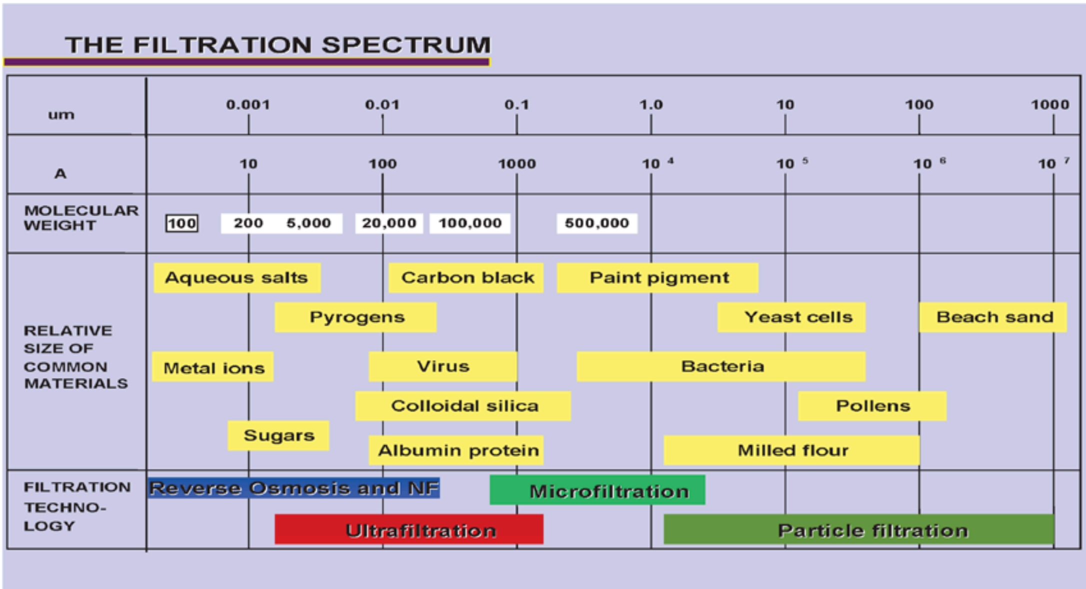


Figure 10-5 Existing California Brackish and Sea Water Desalination Facilities